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(54) **DEEPWATER GROUP PILE FOUNDATION**

(57) A deepwater group pile foundation, comprising: multiple drilled piles (100), the cross-sectional shape of pile tops (100a) of the drilled piles (100) being a square provided with an arc chamfer, a first reinforcement cage (103) being pre-embedded at the interior of each pile top (100a), the cross-sectional shape of the first reinforcement cages (103) being the same as the cross-sectional shape of the pile tops (100a), and the first reinforcement cages (103) each comprising multiple first vertical main ribs (103a) arranged at even intervals; a bearing platform (200), the bearing platform (200) being fixed above the

drilled piles (100), multiple horizontal steel reinforcing bars (105) being provided in the bottom part of the bearing platform (200), the upper ends of the first vertical main ribs (103a) being vertically inserted into the bearing platform (200), and the horizontal steel reinforcing bars (105) within the width range of the first reinforcement cages (103) each passing through gaps between two adjacent first vertical main ribs (103a); and bottom sealing concrete (300), the bottom sealing concrete (300) being located within the height range of the pile tops (100a) below the bearing platform (200).

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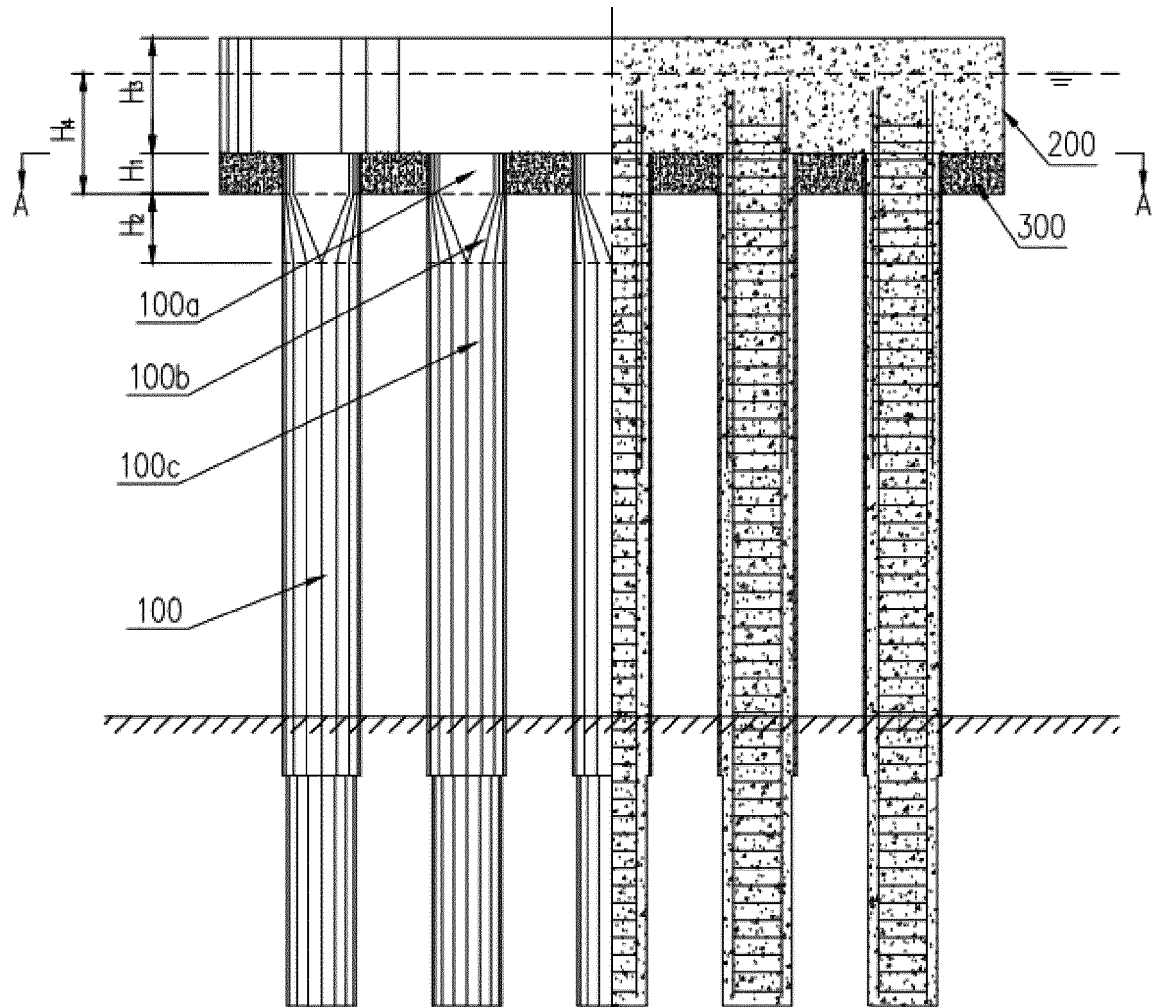


Fig. 1

Description

Field of the Invention

5 **[0001]** The present invention relates to the technical field of bridge engineering, and in particular to a deepwater group pile foundation.

Background of the Invention

10 **[0002]** With the rapid development of China's transportation infrastructure, the construction of sea-crossing bridge engineering is gradually advancing from the offshore to the deep sea. The number of engineering projects is becoming more and more, the scale of the project is getting larger, and the construction environment is becoming more and more complex and diverse. Harsh marine environments such as hurricanes, deep water, rapids, and strong swells will bring great challenges to the construction of the bridge engineering, especially in the design and construction technology of
15 bridge deepwater foundation.

[0003] As a commonly used foundation form for deepwater foundation, the group pile foundation with a high bearing platform is widely used in China's sea-crossing bridge engineering due to its mature technology, rich construction experience and relatively small construction risk. Compared with inland river bridges, the main difference of the deepwater foundation of sea-crossing bridges is that the hydrological environment and meteorological conditions are worse, and
20 the foundation must be able to withstand the huge horizontal forces generated by typhoons, huge waves and spring tides, and can resist the impact force of giant ocean ships. Due to the changeable climate, strong wind, deep water, and high waves at sea, the duration of construction operations allowed for the foundation of the sea-crossing bridges is relatively short. For the group pile foundation with the high bearing platform, under the action of horizontal load, the position with the largest bending moment of the pile foundation often appears at the pile tops, and the structural strength
25 is controlled by the bending resistance, so a large number of reinforcing bars are required at the pile tops. In order to reduce the influence of wave currents on the pile foundation, reduce the scouring at the pier site, and meet the requirements of drilling construction and hole-forming stability, the bridge pile foundation usually adopts circular cross section. The main ribs of the pile foundation reinforcement cages shall be evenly arranged in a circular circumferential direction and anchored in the bearing platform, while the longitudinal and transverse horizontal steel reinforcing bars at the bottom
30 part of the bearing platform need to pass through the pile foundation reinforcement cages when they are arranged.

[0004] Since the main bars of the pile foundation reinforcement cages are evenly arranged in the circular direction, the projection width of the distance between adjacent main bars of the same pile foundation in the longitudinal and transverse directions becomes smaller from the middle to both sides. When the projected width is smaller than the diameter of the horizontal steel reinforcing bars at the bottom part of the bearing platform, it is difficult for the horizontal
35 steel reinforcing bars at the bottom part of the bearing platform to pass through the reinforcement cages smoothly. Especially when the pile foundation reinforcement cages are required to be equipped with two turns of main ribs due to force requirements, the blind area where the horizontal steel reinforcing bars at the bottom part of the bearing platform is difficult to pass through the pile foundation reinforcement cages is larger.

[0005] In the marine environment with harsh wave-current conditions, in order to reduce the wave-current force on the foundation and reduce the scale of the foundation, the bearing platform is usually designed as a streamlined appearance such as pointed end type or round end type. Correspondingly, the pile foundation is arranged in a quincunx shape, and the quincunx-shaped pile foundation arrangement will further increase the width of the blind area where the horizontal steel reinforcing bars in the entire range of the bearing platform are difficult to pass through the pile foundation reinforcement cages. The horizontal steel reinforcing bars at the bottom part of the bearing platform is usually cut off
45 within the width range of the blind area and cannot maintain a full length, which is unfavorable to the structural force. Moreover, the spacing of the horizontal steel reinforcing bars on the bottom surface of the range of the entire bearing platform is uneven, which has a certain adverse effect on the quality of concrete pouring.

[0006] At the same time, the corrosion environment of the sea-crossing bridges is even harsher. In order to ensure the durability of the bridge structure, epoxy reinforcing bars are often used as the reinforcing bars for the bearing platform.
50 However, the construction requirements of the epoxy reinforcing bars are relatively high, in order to avoid the coating layer of the epoxy reinforcing bars being damaged, the main bars at the bottom part of the bearing platform are prohibited from scratching with the pile foundation reinforcement cages when arranging, which undoubtedly greatly increases the construction difficulty of the horizontal steel reinforcing bars at the bottom part of the bearing platform, also increases the period of construction, and make it difficult to guarantee the construction quality of the bearing platform. The construction of the horizontal steel reinforcing bars at the bottom part of the bearing platform of the group pile foundation of large-scale sea-crossing bridges has always been a difficult problem for the construction unit, especially the problem that the horizontal steel reinforcing bars at the bottom part of the bearing platform is difficult to pass through the pile foundation reinforcement cages smoothly.

Summary of the Invention

[0007] The embodiment of the present invention provides a deepwater group pile foundation to solve the problem that the horizontal steel reinforcing bars at the bottom part of the bearing platform of the group pile foundation of the sea-crossing bridge in the related art are difficult to pass through the pile foundation reinforcement cage smoothly, and the pile foundation reinforcement cage exists a blind area that cannot allow the horizontal steel reinforcing bars at the bottom part of the bearing platform to pass through.

[0008] In a first aspect, a deepwater group pile foundation is provided, comprising: a plurality of drilled piles, each of which is provided with a pile top, the cross-sectional shape of the pile top is a square with an arc chamfer, and four straight sides of the square are respectively parallel to longitudinal and transverse directions of the whole deepwater group pile foundation, a first reinforcement cage is pre-embedded at an interior of the pile top, the cross-sectional shape of the first reinforcement cage is the same as that of the pile top, and the first reinforcement cage comprises a plurality of first vertical main ribs arranged at even intervals; a bearing platform, which is fixed above the drilled piles, a plurality of horizontal steel reinforcing bars are provided in a bottom part of the bearing platform, upper ends of the first vertical main ribs are vertically inserted into the bearing platform, and the horizontal steel reinforcing bars within width range of the first reinforcement cage each passes through gaps between two adjacent first vertical main ribs; and bottom sealing concrete, which is located within height range of the pile tops below the bearing platform.

[0009] In some embodiments, the drilled pile further comprises: a pile body, which is located below the pile top, the cross-sectional shape of the pile body is a circle, and a second reinforcement cage is provided at the interior of the pile body, the cross-sectional shape of the second reinforcement cage is the same as that of the pile body, and the second reinforcement cage comprises a plurality of second vertical main ribs arranged at even intervals; and a transition section, which connects the pile top and the pile body, the cross-sectional shape of the transition section is a square with an arc chamfer, and a radius of the arc chamfer of the cross-section of the transition section gradually increases from a top part of the transition section to a bottom part of the transition section along height direction of the transition section, a plurality of third main ribs are pre-embedded at the interior of the transition section, and the third main ribs linearly connect the first vertical main ribs and the second vertical main ribs in one-to-one correspondence.

[0010] In some embodiments, the cross-sectional shape of the pile top is a square with an arc chamfer, and a width of the square cross-section of the pile top is equal to a diameter of the circular cross section of the pile body.

[0011] In some embodiments, a height H_2 of the transition section is greater than or equal to a diameter D of the pile body.

[0012] In some embodiments, the radius r_z of the arc chamfer of the cross section at any height of the transition section is:

$$r_z = r_1 + (D/2 - r_1) \times z / H_2,$$

wherein

z is the height of any cross section in the transition section from the bottom surface of the pile top, H_2 is the height of the transition section, D is a diameter of the pile body, and r_1 is the radius of the arc chamfer of the cross-section of the pile top.

[0013] In some embodiments, the drilled pile further comprises a second steel casing sleeved outside the second reinforcement cage, and the number n_2 of the second vertical main ribs is:

$$n_2 = 4 * \text{Int}([\pi * (D - 2 * (t_2 + \delta_{\text{average}}))] / [4 * (80 + d_2 + \Delta s)]),$$

wherein

π is the ratio of the circumference of a circle to its diameter, D is a diameter of the pile body, t_2 is a wall thickness of the second steel casing, δ_{average} is an average distance between a circumferential centerline of a planar layout of the second vertical main ribs and the inner surface of the second steel casing, d_2 is the diameter of the second vertical main rib, Δs is the amount of spacing adjustment of the second vertical main ribs, and the value of the Δs satisfies: $5 \leq \Delta s \leq 120 - d_2$, and the unit of each parameter in the formula is millimeter.

[0014] In some embodiments, the value range of the height H_1 of the pile top is:

$$H_1 > \gamma_w H_4 [A_c + 0.86 n r_1^2 - n B^2] / [4 n (B - 0.43 r_1) [\tau] + \gamma_c (A_c + 0.86 n r_1^2 - n B^2) + W],$$

wherein

γ_w is the weight of water, γ_c is the weight of concrete, H_4 is the height of the bottom surface of the pile top from a high water level of construction, A_c is the bottom area of the bearing platform, B is the width of the cross-section of the pile top, r_1 is a radius of the arc chamfer of the cross-section of the pile top, n is the number of the drilled piles, $[\tau]$ is allowable bonding strength between the concrete and the steel surface, and W is the weight of construction cofferdam of the bearing platform.

[0015] In some embodiments, the drilled pile further comprises a first steel casing sleeved outside the first reinforcement cage, and part of the first vertical main ribs are arranged at equal intervals along four-side straight sections of the cross-section of the pile top, wherein the spacing s is:

$$s=[4(B-2r_1)+2\pi(r_1-(t_1+f_{\text{average}}))]/n_1,$$

wherein

B is the width of the cross-section of the pile top, r_1 is a radius of the arc chamfer of the cross-section of the pile top, π is the ratio of the circumference of a circle to its diameter, t_1 is a wall thickness of the first steel casing, f_{average} is an average distance between a circumferential centerline of a planar layout of the first vertical main ribs and the inner surface of the first steel casing, and n_1 is the number of the first vertical main ribs in a single turn; and

part of the first vertical main ribs are arranged with equal deflection angles along the arc chamfer sections of the cross-section of the pile top, wherein the size of the deflection angle α is:

$$\alpha=s/(r_1-(t_1+f_{\text{average}})),$$

wherein

s is a spacing of the first vertical main ribs arranged along the four-side straight sections of the cross-section of the pile top, r_1 is the radius of the arc chamfer of the cross-section of the pile top, t_1 is the wall thickness of the first steel casing, and f_{average} is an average distance between the circumferential centerline of the planar layout of the first vertical main ribs and the inner surface of the first steel casing.

[0016] In some embodiments, the drilled pile further comprises a first steel casing sleeved outside the first reinforcement cage, and when 2 turns of the first vertical main ribs are arranged in the first reinforcement cage, the value range of the radius r_1 of the arc chamfer of the cross-section of the pile top is:

$$((340+4d_1)/\pi+t_1+f_2)\leq r_1\leq(1400/\pi+t_1+f_1),$$

wherein

d_1 is a diameter of the first vertical main rib, π is the ratio of the circumference of a circle to its diameter, t_1 is a wall thickness of the first steel casing, f_1 and f_2 represent distances from a circumferential centerline of a planar layout of the first vertical main ribs in the first turn and second turns to the inner surface of the first steel casing respectively, and the unit of each parameter in the formula is millimeter.

[0017] In some embodiments, the value range of the ratio of a thickness H_3 of the bearing platform to a diameter D of the pile body is:

$$H_3/D\geq 1.2$$

[0018] The beneficial effects of the technical solution provided in the present invention comprise:

The present invention provides a deepwater group pile foundation. Due to the fact that the drilled pile is provided with a pile top, the cross-sectional shape of the pile top is a square with an arc chamfer, four straight sides of the square are respectively parallel to longitudinal and transverse directions of the whole deepwater group pile foundation, and a first reinforcement cage is pre-embedded at an interior of the drilled pile, the cross-sectional shape of the first reinforcement cage is the same as that of the pile top, and the first reinforcement cage comprises a plurality of first vertical main ribs which are arranged at even intervals; a bearing platform is fixed above the pile tops, upper ends of the first vertical main

ribs are vertically inserted into the bearing platform, a plurality of horizontal steel reinforcing bars are provided in a bottom part of the bearing platform, and the horizontal steel reinforcing bars each passes through gaps between two adjacent first vertical main ribs; and bottom sealing concrete is located within height range of the pile top below the bearing platform. Therefore, the horizontal steel reinforcing bars at the bottom part of the bearing platform can pass through the width range of the first reinforcing cage smoothly, and there is no blind area within the width range of the first reinforcing cage that cannot allow the horizontal steel reinforcing bars to pass through. All the horizontal steel reinforcing bars in the bearing platform do not need to be cut off, and should be kept in full length, with uniform spacing and proper density. The construction difficulty of the horizontal steel reinforcing bars in the bearing platform is reduced, the quality of the concrete pouring of the bearing platform is guaranteed, the force is better, and the construction period of the bearing platform is shortened.

Brief Description of the Drawings

[0019] In order to better illustrate the technical solution in the embodiments of the present application, the following will briefly introduce the drawings needed in the description of the embodiments, and it is obvious that the drawings in the following description are only a part of embodiments of the present application, for those of ordinary skill in the art, other drawings may also be obtained based on these drawings without any inventive effort.

Fig. 1 is a structural diagram of a deepwater group pile foundation in the embodiment of the present invention;

Fig. 2 is a cross-sectional view of A-A in Fig. 1;

Fig. 3 is a schematic diagram of horizontal steel reinforcing bars in a bearing platform of a deepwater group pile foundation each passing through gaps between two adjacent first vertical main ribs;

Fig. 4 is a front schematic diagram of a single drilled pile in a deepwater group pile foundation in the embodiment of the present invention;

Fig. 5 is a three-dimensional structural diagram of a single drilled pile in a deepwater group pile foundation in the embodiment of the present invention;

Fig. 6 is a cross-sectional diagram of a single drilled pile in a deepwater group pile foundation in the embodiment of the present invention;

Fig. 7 is a cross-sectional view of B-B in Fig. 4;

Fig. 8 is a three-dimensional structural diagram of the first angle of a transition section of a single pile in a deepwater group pile foundation in the embodiment of the present invention;

Fig. 9 is a three-dimensional structural diagram of the second angle of a transition section of a single pile in a deepwater group pile foundation in the embodiment of the present invention;

Fig. 10 is a cross-sectional view of C-C in Fig. 6;

Fig. 11 is a structural diagram of the second reinforcement cage in a deepwater group pile foundation in the embodiment of the present invention;

Fig. 12 is a cross-sectional view of D-D in Fig. 6;

Fig. 13 is a structural diagram of a reinforcement cage in a transition section of a deepwater group pile foundation in the embodiment of the present invention;

Fig. 14 is a cross-sectional view of E-E in Fig. 6;

Fig. 15 is a structural diagram of the first reinforcement cage in a deepwater group pile foundation in the embodiment of the present invention;

Fig. 16 is a schematic diagram of arrangement of longitudinal and transverse horizontal steel reinforcing bars on a

1/4 bottom surface of a bearing platform in a deepwater group pile foundation in the embodiment of the present invention.

[0020] In the figures:

100-drilled pile; 100a-pile top; 100b-transition section; 100c-pile body; 101-steel casing; 101a-the first steel casing; 101c-the second steel casing; 102-concrete pile body; 103-the first reinforcement cage; 103a-the first vertical main rib; 103b-the third main rib; 104-the second reinforcement cage; 104a-the second vertical main rib; 105-horizontal steel reinforcing bar; 200-bearing platform; 300-bottom sealing concrete.

Detailed Description of the Embodiments

[0021] In order to make the purpose, technical solutions and advantages of the embodiments of the present invention clearer, the technical solutions in the embodiments of the present invention will be described clearly and completely in combination with the drawings in the embodiments of the present invention. Obviously, the described embodiments are only a part of the embodiments of the present invention, not all of the embodiments. Based on the embodiments in the present invention, all other embodiments obtained by a person of ordinary skill in the art without inventive efforts shall fall within the protection scope of the present invention.

[0022] The embodiment of the present invention provides a deepwater group pile foundation, which can solve the problem that the horizontal steel reinforcing bars at the bottom part of the bearing platform of the group pile foundation of the sea-crossing bridges are difficult to pass through the blind area of the pile foundation reinforcement cages smoothly.

[0023] As shown in Figs. 1 to 4, 15 and 16, the embodiment of the present invention provides a deepwater group pile foundation, which can comprise a plurality of drilled piles 100, each drilled pile 100 can be provided with a pile top 100a, and the cross-sectional shape of the pile top 100a can be a square with an arc chamfer, in this embodiment, the four corners of the square cross-section of the pile top 100a are all arc chamfers, the four straight sides of the square cross-section are respectively parallel to longitudinal and transverse directions of the whole deepwater group pile foundation, and a first reinforcement cage 103 is pre-embedded at an interior of the drilled pile 100, in this embodiment, the first reinforcement cage 103 is fixed by a plurality of first vertical main ribs 103a and stirrups by welding, the first vertical main ribs 103a are perpendicular to the cross-section of the drilled pile 100, the cross-sectional shape of the first reinforcement cage 103 can be the same as that of the pile top 100a, and the first vertical main ribs 103a can be arranged at even intervals, that is, part of the first vertical main ribs 103a can be arranged at even intervals along the four-side straight sections of the cross-section of the pile top 100a, and another part of the first vertical main ribs 103a can be arranged at equal deflection angles along the four arc chamfering sections of the cross-section of the pile tops 100a, and the first vertical main ribs 103a can be arranged with the longitudinal and transverse centerlines of the pile foundation section as the axis of symmetry, so the plane layout of the first vertical main ribs 103a of each pile top 100a within the entire foundation range is parallel to each other. The deepwater group pile foundation further comprises a bearing platform 200, the bearing platform 200 can be fixed above the pile tops 100a, and upper ends of the first vertical main ribs 103a can be vertically inserted into the bearing platform 200, in the embodiment, the first vertical main ribs 103a of each drilled pile 100 within the entire bearing platform 200 are arranged parallel to each other, a plurality of horizontal steel reinforcing bars 105 can be provided in a bottom part of the bearing platform 200, and the horizontal steel reinforcing bars 105 within width range of the first reinforcement cage 103 can each pass through gaps between two adjacent first vertical main ribs 103a. The deepwater group pile foundation further comprises bottom sealing concrete 300, the bottom sealing concrete 300 is located within height range of the pile tops 100a below the bearing platform 200. When the first vertical main ribs 103a are located within the range of the four-side straight sections of the cross-section of each first reinforcement cage 103, the planar layout of the first vertical main ribs 103a is parallel to the longitudinal and transverse directions of the entire foundation, and because the layout of horizontal steel reinforcing bars 105 at the bottom part of the bearing platform are also parallel to the longitudinal and transverse directions of the entire foundation, it is only necessary to set the clear distance between the two adjacent first vertical main ribs 103a to be greater than the diameter of the horizontal steel reinforcing bars 105 at the bottom part of the bearing platform, so that the horizontal steel reinforcing bars 105 can smoothly pass through the gaps between the two adjacent first vertical main ribs 103a within the straight section of the cross-section of each first steel reinforcement cage 103, there are 2 or 4 first vertical main ribs 103a in each drilled pile 100 within the arc chamfer section of the cross-section of the first reinforcement cage 103 on average, and the horizontal steel reinforcing bars 105 can also smoothly pass through the gaps between two adjacent first vertical main ribs 103a within the arc chamfer section of the cross-section of the first reinforcement cage 103 through local bending, therefore, the horizontal steel reinforcing bars 105 at the bottom part of the bearing platform 200 can smoothly pass through the width range of the first reinforcement cage 103, there is no blind area within the width range of the first reinforcement cage 103 that cannot allow the horizontal steel reinforcing bars 105 to pass through. All the horizontal steel reinforcing bars 105 at the bottom part of the bearing platform 200 need not to be cut off, and can be kept in full length, and the spacing between the adjacent horizontal steel reinforcing bars 105 is uniform and the density is appropriate,

the construction difficulty of the horizontal steel reinforcing bars 105 at the bottom part of the bearing platform 200 is reduced, the concrete pouring quality of the bearing platform 200 is guaranteed, the force is better, and the construction period of the bearing platform 200 is shorten.

[0024] As shown in Figs. 4 to 11 and Fig. 13, in some embodiments, the drilled pile 100 can further comprise a pile body 100c and a transition section 100b. The pile body 100c can be located below the pile top 100a, the cross section of the pile body 100c can be a circle, and a second reinforcement cage 104 can be provided at the interior of the pile body 100c, the cross-sectional shape of the second reinforcement cage 104 can be the same as that of the pile body 100c, both of which are circular, and the second reinforcement cage 104 can comprise a plurality of second vertical main ribs 104a arranged at even intervals, that is, a plurality of second vertical main ribs 104a can be arranged at even intervals along the circular ring of the cross-section of the second reinforcement cage 104 respectively. The transition section 100b can be located between the pile top 100a and the pile body 100c, and the pile top 100a and the pile body 100c can be connected together through the transition section 100b, the cross-sectional shape of the transition section 100b is a square with an arc chamfer, and the radius of the arc chamfer of the cross-section of each transition section 100b changes continuously along the height direction of the transition section 100b, in this embodiment, the radius of the arc chamfer of the cross-section of each transition section 100b gradually increases from the top part of the transition section 100b to the bottom part of the transition section 100b along height direction of the transition section 100b, a plurality of third main ribs 103b can be pre-embedded at the interior of each transition section 100b, and the third main ribs 103b linearly connect the first vertical main ribs 103a and the second vertical main ribs 104a in one-to-one correspondence. Therefore, the cross-section of the pile top 100a of each drilled pile 100 can be designed as a square with an arc chamfer, and the pile body 100c of the drilled pile 100 can be designed as a circle, the square pile top 100a with the arc chamfers can make the horizontal steel reinforcing bars 105 at the bottom part of the bearing platform 200 pass through the width range of the first reinforcement cage 103 smoothly, and the circular pile body 100c can reduce the influence of wave currents on the drilled piles 100, reduce the erosion at the pier position, and meet the requirements of drilling construction and hole-forming stability.

[0025] As shown in Fig. 8 and Fig. 9, in some embodiments, the transition sections 100b can be formed through gradually increasing the radius of the arc chamfers of the pile top 100a towards the direction close to the pile body 100c, so that the transition section 100b has an inclined side, and the area of the cross-section of the transition section 100b gradually decreases from the bottom surface of the pile top 100a to the top surface of the pile body 100c, through setting in this way, the third main ribs 103b can linearly connect the first vertical main ribs 103a and the second vertical main ribs 104a in one-to-one correspondence without excessive bending.

[0026] As shown in Fig. 7, in some embodiments, the cross-section of the pile top 100a can be a square with an arc chamfer, the width B of the cross-section of the pile top 100a can be equal to the diameter D of the cross-section of the pile body 100c, and the ratio of the width B of the cross-section of the pile top 100a to the diameter D of the cross-section of the pile body 100c can meet the following requirements: $B/D=1$, that is, the cross-section of the pile top 100a is a circumscribed square of the cross-section of the pile body 100c, and the area of the cross-section of the pile top 100a is 1.2 times the area of the cross-section of the pile body 100c, the bending resistance moment of the cross-section of the pile top 100a is 1.7 times of the bending resistance moment of the cross-section of the pile body 100c, so under the same load, the amount of main ribs of the reinforcement cage in the drilled pile 100 can be effectively reduced.

[0027] As shown in Fig. 4, Fig. 5 and Fig. 7, in some embodiments, the height H_2 of the transition section 100b can be greater than or equal to the diameter D of the pile body 100c, which ensures that the load transfer between the pile top 100a and the pile body 100c is smoother and avoids the stress concentration caused by the sudden change of the pile foundation.

[0028] As shown in Figs. 7 to 9, Fig. 12 and Fig. 14, in some embodiments, the radius r_z of the arc chamfer of the cross section at any height of the transition section 100b can be:

$$r_z = r_1 + (D/2 - r_1) \times z / H_2,$$

wherein

z can be the height of any cross section in the transition section 100b from the bottom surface of the pile top 100a, r_z can be the radius of the arc chamfer of the cross-section of the transition section 100b at the height z from the bottom surface of the pile top 100a, H_2 can be the height of the transition section 100b, D can be the diameter of the pile body 100c, and r_1 can be the radius of the arc chamfer of the cross-section of the pile top 100a.

[0029] As shown in Fig. 6, in some embodiments, the drilled pile 100 can be constructed through pouring underwater concrete into the steel casing 101 pre-embedded with the reinforcement cage and into the drill hole, in this embodiment, the shape of the steel casing 101 is in a square top and a round body, and the underwater concrete is solidified to form a concrete pile body 102, and the concrete pile body 102 and the steel casing 101 are combined to form a drilled pile 100.

[0030] As shown in Fig. 10 and Fig. 11, in some embodiments, the drilled pile 100 can further comprise a second steel casing 101c sleeved outside the second reinforcement cage 104, the second reinforcement cage 104 can have 1 turn or 2 turns of the second vertical main ribs 104a, the number of turns of the second reinforcement cage 104 can be equal to that of the first reinforcement cage 103, the number of the second vertical main ribs 104a in a single turn can be equal to that of the first vertical main ribs 103a in a single turn, and the number of the second vertical main ribs 104a in each single turn can be equal, and the number n_2 of the second vertical main ribs 104a can be:

$$n_2 = 4 * \text{Int}([\pi * (D - 2 * (t_2 + \delta_{\text{average}}))] / [4 * (80 + d_2 + \Delta s)]),$$

wherein

π is the ratio of the circumference of a circle to its diameter, D is the diameter of the pile body 100c, t_2 is the wall thickness of the second steel casing 101c, δ_{average} is the average distance between the circumferential centerline of the planar layout of the second vertical main ribs 104a and the inner surface of the second steel casing 101c, when only one turn of the second vertical main ribs 104a is arranged, $\delta_{\text{average}} = \delta_1$, and when two turns of the second vertical main ribs 104a are arranged, $\delta_{\text{average}} = (\delta_1 + \delta_2) / 2$, δ_1 and δ_2 represent the distances from the circumferential centerline of the planar layout of the first and second turns of the second vertical main ribs 104a to the inner surface of the second steel casing 101c respectively, d_2 can be the diameter of the second vertical main rib 104a, when the second reinforcement cage 104 are arranged with two turns of the second vertical main ribs 104a, and the diameters of the second vertical main ribs 104a are not equal, d_2 can take the maximum value, Δs is the amount of spacing adjustment of the second vertical main ribs 104a, and the value of the Δs satisfies: $5 \leq \Delta s \leq 120 - d_2$, and the unit of each parameter in the formula is millimeter.

[0031] As shown in Fig. 1 and Fig. 2, in some embodiments, the value range of the height H_1 of the pile top 100a can be:

$$H_1 > \gamma_w H_4 [A_c + 0.86 n r_1^2 - n B^2] / [4 n (B - 0.43 r_1) [\tau] + \gamma_c (A_c + 0.86 n r_1^2 - n B^2) + W],$$

wherein

γ_w is the weight of water, γ_c is the weight of concrete, H_4 is the height of the bottom surface of the pile top 100a from the high water level of construction, A_c is bottom area of the bearing platform 200, B is the width of the cross-section of the pile top 100a, r_1 is the radius of the arc chamfer of the cross-section of the pile top 100a, n is the number of the drilled piles 100, $[\tau]$ is allowable bonding strength between the concrete and the steel surface, and W is the weight of construction cofferdam of the bearing platform 200.

[0032] As shown in Fig. 14 and Fig. 15, in some embodiments, the drilled pile 100 can further comprise a first steel casing 101a sleeved outside the first reinforcement cage 103, a plane rectangular coordinate system can be established on the cross-section of the drilled pile 100 with the center point of the cross section as the origin O , in which the X axis can be parallel to the transverse direction of the foundation, and the Y axis can be parallel to the longitudinal direction of the foundation. The cross-section of each drilled pile 100 can be divided into four quadrants, the first vertical main ribs 103a in each quadrant are arranged with the X axis and the Y axis as the symmetrical axis, the first vertical main ribs 103a in the pile top 100a of each drilled pile 100 in the range of the whole bearing platform are arranged in parallel with each other, and part of the first vertical main ribs 103a in the pile top 100a can be arranged at equal intervals along the four-side straight sections of the cross-section of the pile top 100a, and the spacing s can be:

$$s = [4(B - 2r_1) + 2\pi(r_1 - (t_1 + f_{\text{average}}))] / n_1,$$

wherein

B can be the width of the cross-section of the pile top 100a, r_1 can be the radius of the arc chamfer of the cross-section of the pile top 100a, π can be the ratio of the circumference of a circle to its diameter, t_1 can be the wall thickness of the first steel casing 101a, f_{average} can be the average distance between the circumferential centerline of the planar layout of the first vertical main ribs 103a and the inner surface of the first steel casing 101a, when only one turn of the first vertical main ribs 103a is arranged, $f_{\text{average}} = \delta_1$, and when two turns of the first vertical main ribs 103a are arranged, $f_{\text{average}} = (f_1 + f_2) / 2$, f_1 and f_2 represent the distances from the circumferential centerline of the planar layout of the first and second turns of the first vertical main ribs 103a to the inner surface of the first steel casing 101a respectively, and n_1 can be the number of the first vertical main ribs 103a in a single turn, in which n_1 can be equal to n_2 ; and

other part of the first vertical main ribs 103a can be arranged with equal deflection angles along the arc chamfer sections of the cross-section of the pile top 100a, and the size of the deflection angle α can be:

$$\alpha = s / (r_1 - (t_1 + f_{\text{average}})),$$

wherein

s can be the spacing of the first vertical main ribs 103a arranged along the four-side straight sections of the cross-section of the pile tops 100a, r_1 can be the radius of the arc chamfer of the cross-section of the pile top 100a, t_1 can be the wall thickness of the first steel casing 101a, f_{average} can be the average distance between the circumferential centerline of the planar layout of the first vertical main ribs 103a and the inner surface of the first steel casing 101a, when only one turn of the first vertical main ribs 103a is arranged, $f_{\text{average}} = f_1$, and when two turns of the first vertical main ribs 103a are arranged, $f_{\text{average}} = (f_1 + f_2) / 2$, f_1 and f_2 represent the distances from the circumferential centerline of the planar layout of the first and second turns of the first vertical main ribs 103a to the inner surface of the first steel casing 101a respectively.

[0033] As shown in Fig. 14 and Fig. 15, in some embodiments, the drilled pile 100 can further comprise a first steel casing 101a sleeved outside the first reinforcement cage 103, and when 2 turns of the first vertical main ribs 103a are arranged in the first reinforcement cage 103, the value range of the radius r_1 of the arc chamfer of the cross-section of the pile top 100a can be:

$$((340 + 4d_1) / \pi + t_1 + f_2) \leq r_1 \leq (1400 / \pi + t_1 + f_1),$$

wherein

d_1 can be the diameter of the first vertical main rib 103a, when the diameters of the two turns of the first vertical main rib 103a are not equal, d_1 can take the maximum value, π can be the ratio of the circumference of a circle to its diameter, t_1 can be the wall thickness of the first steel casing 101a, f_1 and f_2 can represent distances from the circumferential centerline of the planar layout of the first vertical main rib 103a in the first turn and second turns to the inner surface of the first steel casing 101a respectively, and the unit of each parameter in the formula is millimeter.

[0034] As shown in Fig. 1 and Fig. 7, in some embodiments, the ratio of the thickness H_3 of the bearing platform 200 to the diameter D of the pile body 100c can be: $H_3 / D \geq 1.2$, so as to ensure the stress safety of the bearing platform 200 and reduce the amount of horizontal steel reinforcing bars at the bottom part of the bearing platform 200.

[0035] As shown in Fig. 1, in some embodiments, the thickness of the bottom sealing concrete 300 can be equal to the height of the pile top 100a, since the cross-section of the pile top 100a can be a square section with an arc chamfer, the inner support of the steel box cofferdam and the surfaces of the pile tops 100a are plane supports when the steel box cofferdam is lowered during the construction of the bearing platform 200, compared with the curved support of the circular pile tops, the internal support is more stable, the force transmission is more reliable, the integrity is better, the construction is more convenient, the bottom sealing concrete 300 is less affected by the wave-current disturbance during pouring, and the bottom sealing quality is better.

[0036] The principle of a deepwater group pile foundation in the embodiment of the present invention is as follows: Because the deepwater group pile foundation can comprise a plurality of drilled piles 100, each of the drilled pile 100 can be provided with a pile top 100a, the cross-sectional shape of the pile top 100a can be a square with an arc chamfer, and four straight sides of the square are respectively parallel to longitudinal and transverse directions of the whole deepwater group pile foundation, a first reinforcement cage 103 can be pre-embedded at an interior of each pile top 100a, the cross-sectional shape of the first reinforcement cage 103 can be the same as that of the pile top 100a, the first reinforcement cage 103 can comprise a plurality of first vertical main ribs 103a and the first vertical main ribs 103a can be arranged at even intervals, that is, part of the first vertical main ribs 103a can be arranged at equal intervals along the four-side straight sections of the cross-section of the pile top 100a, and the other part of the first vertical main ribs 103a can be arranged at equal deflection angles along the four arc chamfer sections of the cross-section of the pile top 100a. The deepwater group pile foundation further comprises a bearing platform 200, the bearing platform 200 can be fixed above the pile tops 100a, upper ends of the first vertical main ribs 103a can be vertically inserted into the bearing platform 200, a plurality of horizontal steel reinforcing bars 105 can be provided in the bottom part of the bearing platform 200, and the horizontal steel reinforcing bars 105 can each pass through gaps between two adjacent first vertical main ribs 103a. The deepwater group pile foundation further comprises a bottom sealing concrete 300, the bottom sealing concrete 300 is located within height range of the pile top 100a below the bearing platform 200, when the first vertical main ribs 103a are located within the range of the four-sided straight sections of the cross-section of the first reinforcement

cage 103, the planar layout of the first vertical main ribs 103a is parallel to the longitudinal and transverse directions of the entire foundation, and because the horizontal steel reinforcing bars 105 at the bottom part of the bearing platform are also parallel to the longitudinal and transverse directions of the entire foundation, it is only necessary to set the clear distance between the two adjacent first vertical main ribs 103a to be greater than the diameter of the horizontal steel reinforcing bars 105 at the bottom part of the bearing platform 200, and the horizontal steel reinforcing bars 105 can smoothly pass through the gaps between the two adjacent first vertical main ribs 103a within the straight section of the cross-section of the first steel reinforcement cage 103, there are 2 or 4 first vertical main ribs 103a in each drilled pile 100 within the arc chamfer section of the cross-section of each first reinforcement cage 103 on average, and the horizontal steel reinforcing bars 105 can also smoothly pass through the gaps between two adjacent first vertical main ribs 103a within the arc chamfer section of the cross-section of each first reinforcement cage 103 through local bending, therefore, the horizontal steel reinforcing bars 105 at the bottom part of the bearing platform 200 can smoothly pass through the width range of the first reinforcement cage 103, there is no blind area within the width range of the first reinforcement cage 103 that cannot allow the horizontal steel reinforcing bars 105 to pass through. All the horizontal steel reinforcing bars 105 in the bottom part of the bearing platform 200 do not need to be cut off, and should be kept in full length, with uniform spacing and proper density. The construction difficulty of the horizontal steel reinforcing bars 105 in the bottom part of the bearing platform 200 is reduced, the quality of the concrete pouring of the bearing platform 200 is guaranteed, the force is better, and the construction period of the bearing platform 200 is shortened.

[0037] The cross-section of each pile top 100a can be a square section with an arc chamfer, and the four straight sides of the square can be parallel to the longitudinal and transverse directions of the foundation. For the foundation, the longitudinal and transverse directions are often the most unfavorable directions for the structure to bear force, and when the square section is arranged parallel to the longitudinal and transverse directions of the foundation, the axis direction corresponding to the maximum section bending resistance moment is the same as the direction of the bending moment. Therefore, when subjected to the same bending moment, the section stress is the smallest, which is the most reasonable from a mechanical point of view.

[0038] Since the width B of the cross-section of the pile top 100a can be equal to the diameter D of the cross-section of the pile body 100c, that is, the cross-section of each pile top 100a is the outer tangent square of the cross-section of the pile body 100c, and the circumference of the cross-section of each pile top 100a is 1.2 times of the circumference of the cross-section of the pile body 100c, when the bearing platform 200 performs the punching shear calculation, the equivalent punching shear area of the calculated punching cone generated by the pile top 100a is larger than that of the circular pile top, so under the condition of bearing the same load, the square pile top can effectively reduce the required thickness of the bearing platform, which is about 0.8 times of the required thickness of the circular pile top, which reduces the engineering amount of the foundation.

[0039] Since the bottom sealing concrete 300 is located within the height range of the pile tops 100a below the bearing platform 200, the cross-section of each pile top 100a is a square section with an arc chamfer, and the circumference of the cross-section of each pile top 100a is larger than that of the pile body 100c, which is about 1.2 times the circumference of the cross-section of the pile body 100c. Since the bonding area of the pile top 100a and the bottom sealing concrete 300 per unit height is proportional to the circumference of the section of the pile tops 100a, under the condition of providing the same anti-floating bonding force, the required thickness of the bottom sealing concrete 300 is smaller, about 0.8 times the thickness required for the circular pile tops of the same width, which reduces the work quantity of the foundation.

[0040] Since the cross-section of the pile top 100a can be a square section with an arc chamfer, and the square section of the pile top 100a can be the outer tangent square of the circular section of the pile body 100c, the thickness of the bearing platform 200 and the bottom sealing concrete 300 of the group pile foundation can be effectively reduced, thus reducing the dead weight of the foundation. For friction pile foundation, the required pile length of the foundation can be shortened and the engineering cost can be reduced.

[0041] Since the cross-section of the pile top 100a can be a square section with an arc chamfer, the inner support of the steel box cofferdam and the surfaces of the pile tops 100a are plane supports when the steel box cofferdam is lowered during the construction of the bearing platform 200, compared with the curved support of the circular pile tops, the internal support is more stable, the force transmission is more reliable, the integrity is better, the construction is more convenient, the bottom sealing concrete 300 is less affected by the wave-current disturbance during pouring, and the bottom sealing quality is better.

[0042] In the description of the present invention, it should be noted that the orientation or positional relationship indicated by the terms "upper", "lower", etc. are based on the orientation or positional relationship shown in the drawings, which is only for the convenience of describing the present invention and simplifying the description, instead of indicating or implying that the pointed device or element must have a specific orientation, be configured and operated in a specific orientation, therefore it may not be understood as a limitation of the present invention. Unless otherwise clearly specified and limited, the terms "installation", "connected" and "connection" should be understood in a broad sense. For example, it can be a fixed connection, a detachable connection, or an integral connection; further can be a mechanical connection, or an electrical connection; further can be directly connected, or indirectly connected through an intermediate medium,

or can be the internal communication between two components. For those of ordinary skill in the art, the specific meanings of the above-mentioned terms in the present application may be understood according to specific circumstances.

[0043] It should be noted that relational terms such as "first" and "second" are only for distinguishing one entity or operation from another entity or operation in the present invention, and do not necessarily require or imply any such actual relationship or order between these entities or operations. Moreover, the terms "include", "comprise" or any other variants thereof are intended to cover non-exclusive inclusion, so that a process, method, article or device comprising a series of elements not only comprises those elements, but also comprises those that are not explicitly listed, or further comprises elements inherent to the process, method, article, or device. If there are no more restrictions, the elements defined by the sentence "comprising a..." does not exclude the existence of other same elements in the process, method, article, or device comprising the elements.

[0044] The above-mentioned are only the embodiments of the present invention, so that those skilled in the art may understand or implement the present invention. For those skilled in the art, various modifications to these embodiments will be obvious, and the general principles defined herein may be implemented in other embodiments without departing from the spirit or scope of the present invention. Therefore, the present invention will not be limited to the embodiments shown in this document, but will be subject to the widest scope consistent with the principles and novel features applied herein.

Claims

1. A deepwater group pile foundation, comprising:

a plurality of drilled piles (100), each of which is provided with a pile top (100a), the cross-sectional shape of the pile top (100a) is a square with an arc chamfer, and four straight sides of the square are respectively parallel to longitudinal and transverse directions of the whole deepwater group pile foundation, a first reinforcement cage (103) is pre-embedded at an interior of the pile top (100a), the cross-sectional shape of the first reinforcement cage (103) is the same as that of the pile top (100a), and the first reinforcement cage (103) comprises a plurality of first vertical main ribs (103a) arranged at even intervals;

a bearing platform (200), which is fixed above the drilled piles (100), a plurality of horizontal steel reinforcing bars (105) are provided in a bottom part of the bearing platform (200), upper ends of the first vertical main ribs (103a) are vertically inserted into the bearing platform (200), and the horizontal steel reinforcing bars (105) within width range of the first reinforcement cage (103) each passes through gaps between two adjacent first vertical main ribs (103a); and

bottom sealing concrete (300), which is located within height range of the pile tops (100a) below the bearing platform (200).

2. The deepwater group pile foundation according to claim 1, wherein the drilled pile (100) further comprises:

a pile body (100c), which is located below the pile top (100a), the cross-sectional shape of the pile body (100c) is a circle, a second reinforcement cage (104) is provided at the interior of the pile body (100c), the cross-sectional shape of the second reinforcement cage (104) is the same as that of the pile body (100c), and the second reinforcement cage (104) comprises a plurality of second vertical main ribs (104a) arranged at even intervals; and

a transition section (100b), which connects the pile top (100a) and the pile body (100c), the cross-sectional shape of the transition section (100b) is a square with an arc chamfer, and a radius of the arc chamfer of the cross-section of the transition section (100b) gradually increases from a top part of the transition section (100b) to a bottom part of the transition section (100b) along height direction of the transition section (100b), a plurality of third main ribs (103b) are pre-embedded at the interior of the transition section (100b), and the third main ribs (103b) linearly connect the first vertical main ribs (103a) and the second vertical main ribs (104a) in one-to-one correspondence.

3. The deepwater group pile foundation according to claim 2, wherein the cross-sectional shape of the pile top (100a) is a square with an arc chamfer, and a width of the square cross-section of the pile top (100a) is equal to a diameter of the circular cross section of the pile body (100c).

4. The deepwater group pile foundation according to claim 2, wherein a height H_2 of the transition section (100b) is greater than or equal to a diameter D of the pile body (100c).

5. The deepwater group pile foundation according to claim 2, wherein the radius r_z of the arc chamfer of the cross section at any height of the transition section (100b) is:

$$r_z = r_1 + (D/2 - r_1) \times z / H_2,$$

wherein

z is the height of any cross section in the transition section (100b) from the bottom surface of the pile top (100a), H_2 is the height of the transition section (100b), D is a diameter of the pile body (100c), and r_1 is the radius of the arc chamfer of the cross-section of the pile top (100a).

6. The deepwater group pile foundation according to claim 2, wherein the drilled pile (100) further comprises a second steel casing (101c) sleeved outside the second reinforcement cage (104), and the number n_2 of the second vertical main ribs (104a) is:

$$n_2 = 4 * \text{Int}([\pi * (D - 2 * (t_2 + \delta_{\text{average}}))] / [4 * (80 + d_2 + \Delta s)]),$$

wherein

π is the ratio of the circumference of a circle to its diameter, D is a diameter of the pile body (100c), t_2 is a wall thickness of the second steel casing (101c), δ_{average} is an average distance between a circumferential centerline of a planar layout of the second vertical main ribs (104a) and the inner surface of the second steel casing (101c), d_2 is the diameter of the second vertical main rib (104a), Δs is the amount of spacing adjustment of the second vertical main ribs (104a), and the value of the Δs satisfies: $5 \leq \Delta s \leq 120 - d_2$, and the unit of each parameter in the formula is millimeter.

7. The deepwater group pile foundation according to claim 1, wherein the value range of the height H_1 of the pile top (100a) is:

$$H_1 > \gamma_w H_4 [A_c + 0.86 n r_1^2 - n B^2] / [4 n (B - 0.43 r_1) [\tau] + \gamma_c (A_c + 0.86 n r_1^2 - n B^2) + W],$$

wherein

γ_w is the weight of water, γ_c is the weight of concrete, H_4 is the height of the bottom surface of the pile top (100a) from a high water level of construction, A_c is the bottom area of the bearing platform (200), B is the width of the cross-section of the pile top (100a), r_1 is a radius of the arc chamfer of the cross-section of the pile top (100a), n is the number of the drilled piles (100), $[\tau]$ is allowable bonding strength between the concrete and the steel surface, and W is the weight of construction cofferdam of the bearing platform (200).

8. The deepwater group pile foundation according to claim 1, wherein the drilled pile (100) further comprises a first steel casing (101a) sleeved outside the first reinforcement cage (103), and part of the first vertical main ribs (103a) are arranged at equal intervals along four-side straight sections of the cross-section of the pile top (100a), wherein the spacing s is:

$$s = [4(B - 2r_1) + 2\pi(r_1 - (t_1 + f_{\text{average}}))] / n_1,$$

wherein

B is the width of the cross-section of the pile top (100a), r_1 is a radius of the arc chamfer of the cross-section of the pile top (100a), π is the ratio of the circumference of a circle to its diameter, t_1 is a wall thickness of the first steel casing (101a), f_{average} is an average distance between a circumferential centerline of a planar layout of the first vertical main ribs (103a) and the inner surface of the first steel casing (101a), and n_1 is the number of the first vertical main ribs (103a) in a single turn; and part of the first vertical main ribs (103a) are arranged with equal deflection angles along the arc chamfer sections

of the cross-section of the pile top (100a), wherein the size of the deflection angle α is:

$$\alpha = s / (r_1 - (t_1 + f_{\text{average}})),$$

wherein

s is a spacing of the first vertical main ribs (103a) arranged along the four-side straight sections of the cross-section of the pile top (100a), r_1 is the radius of the arc chamfer of the cross-section of the pile top (100a), t_1 is the wall thickness of the first steel casing (101a), and f_{average} is an average distance between the circumferential centerline of the planar layout of the first vertical main ribs (103a) and the inner surface of the first steel casing (101a).

9. The deepwater group pile foundation according to claim 1, wherein the drilled pile (100) further comprises a first steel casing (101a) sleeved outside the first reinforcement cage (103), and when 2 turns of the first vertical main ribs (103a) are arranged in the first reinforcement cage (103), the value range of the radius r_1 of the arc chamfer of the cross-section of the pile top (100a) is:

$$((340 + 4d_1) / \pi + t_1 + f_2) \leq r_1 \leq (1400 / \pi + t_1 + f_1),$$

wherein

d_1 is a diameter of the first vertical main rib (103a), π is the ratio of the circumference of a circle to its diameter, t_1 is a wall thickness of the first steel casing (101a), f_1 and f_2 represent distances from a circumferential centerline of a planar layout of the first vertical main ribs (103a) in the first turn and second turns to the inner surface of the first steel casing (101a) respectively, and the unit of each parameter in the formula is millimeter.

10. The deepwater group pile foundation according to claim 2, wherein the value range of the ratio of a thickness H_3 of the bearing platform (200) to a diameter D of the pile body (100c) is:

$$H_3 / D \geq 1.2.$$

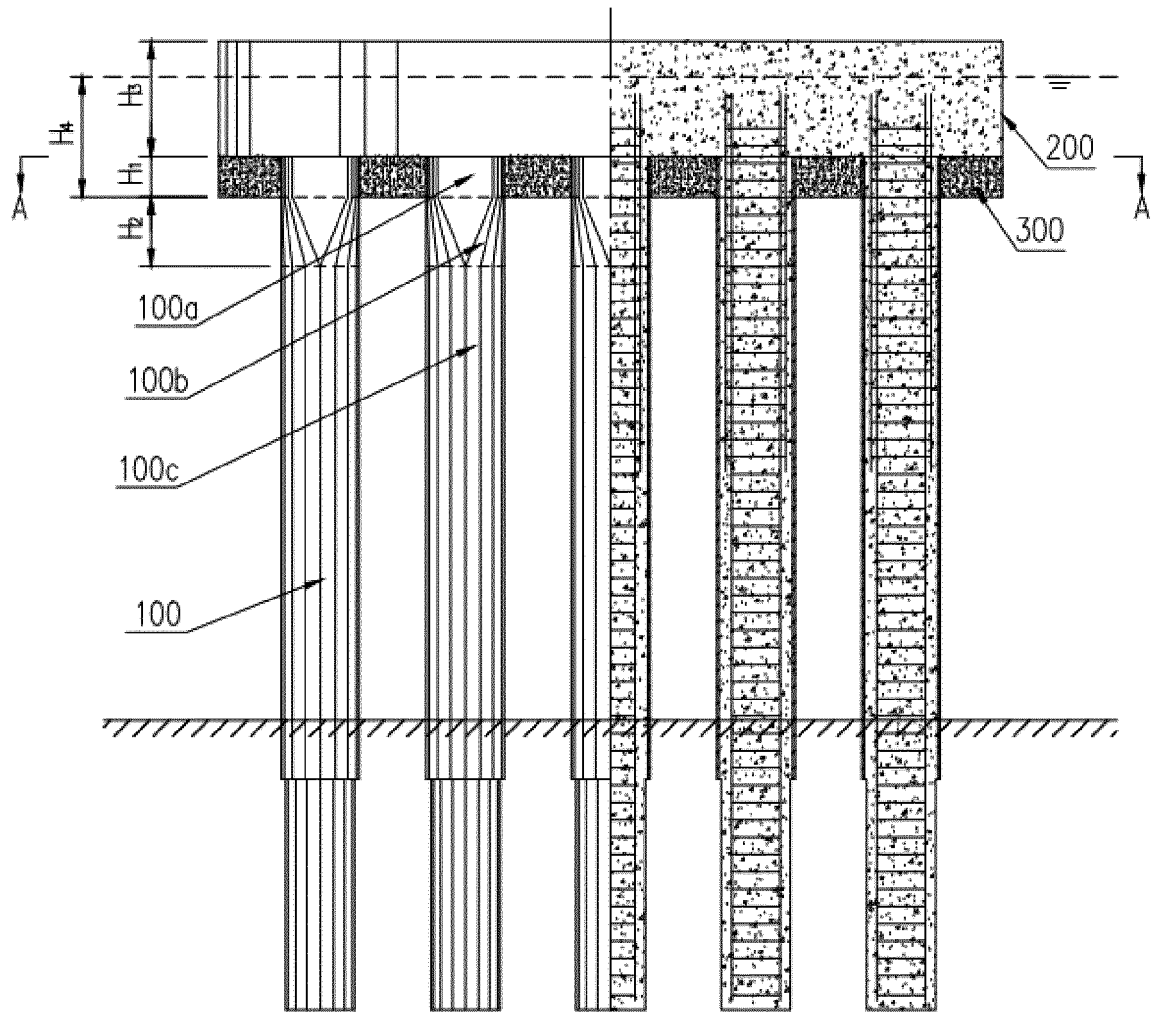


Fig. 1

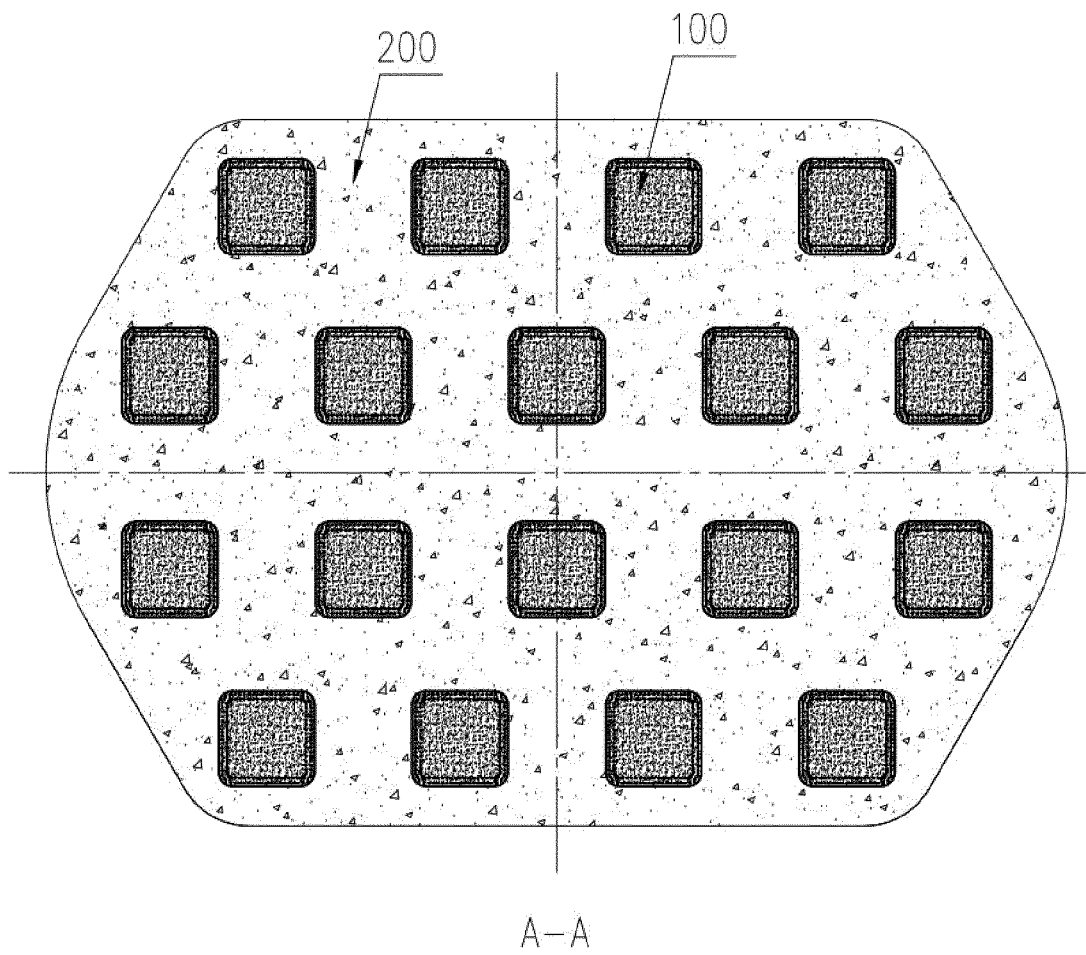


Fig. 2

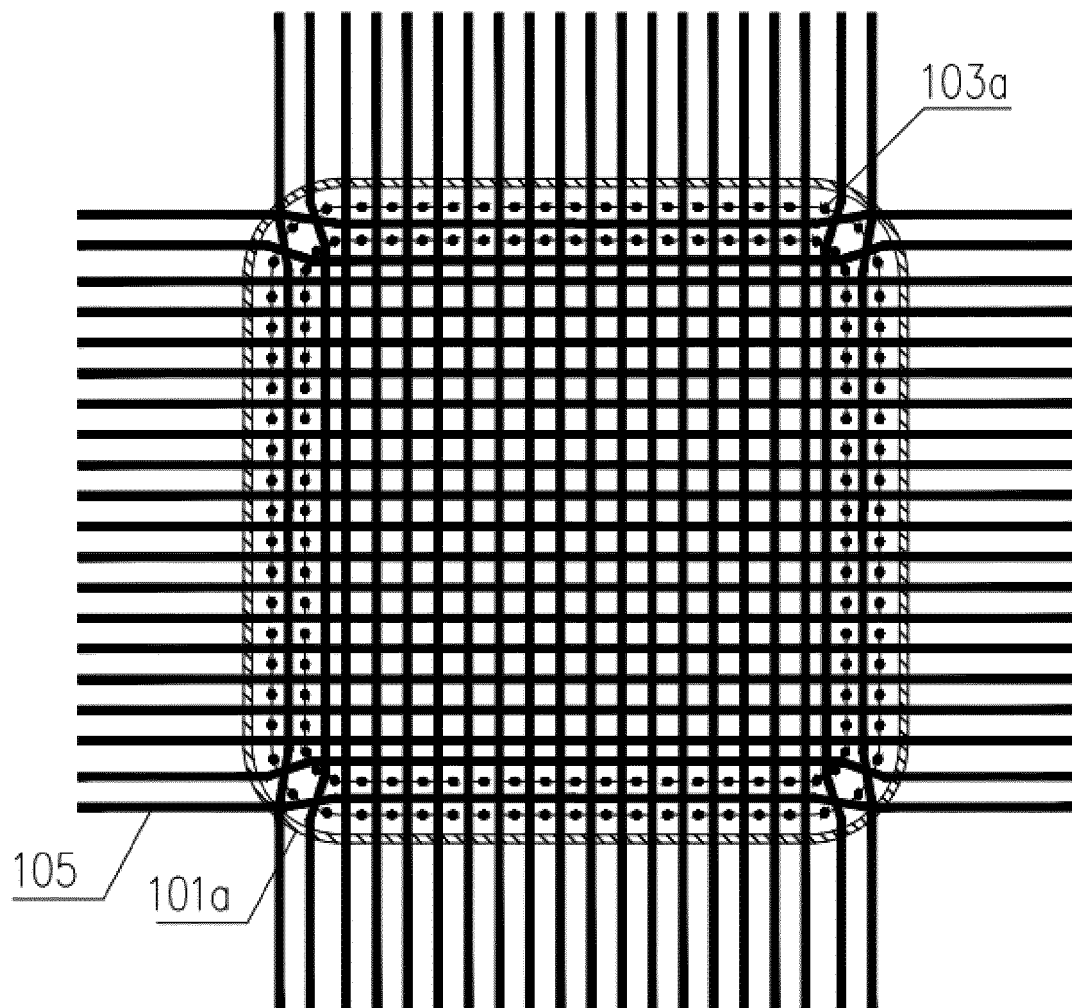


Fig. 3

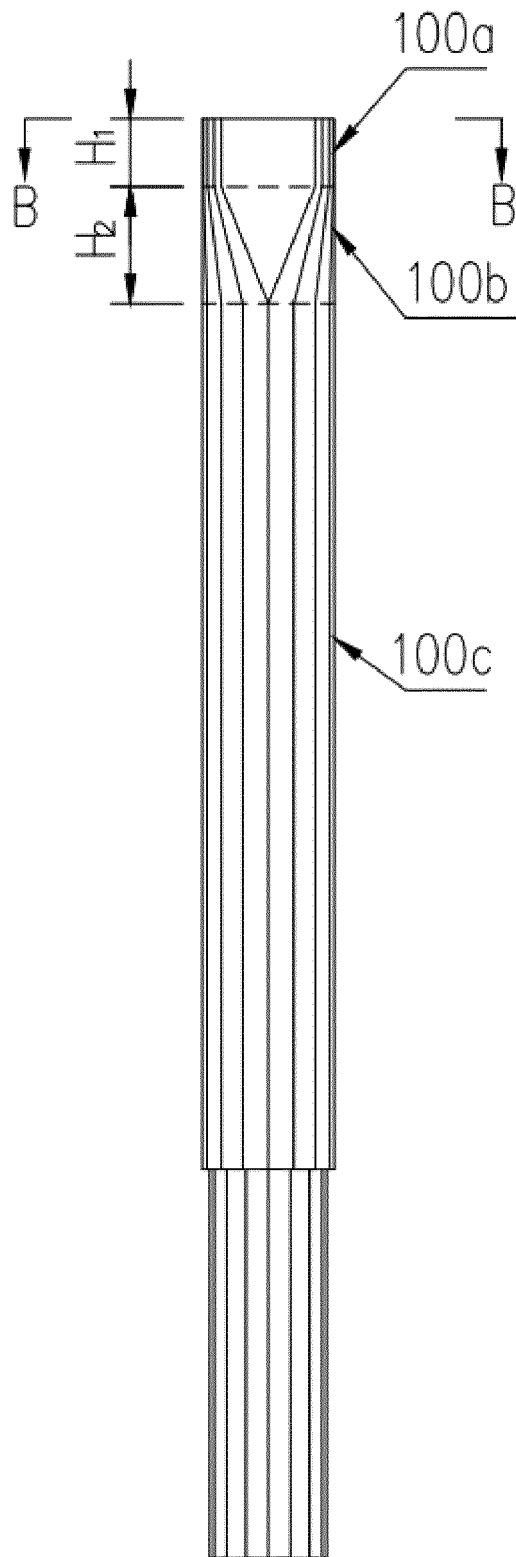


Fig. 4

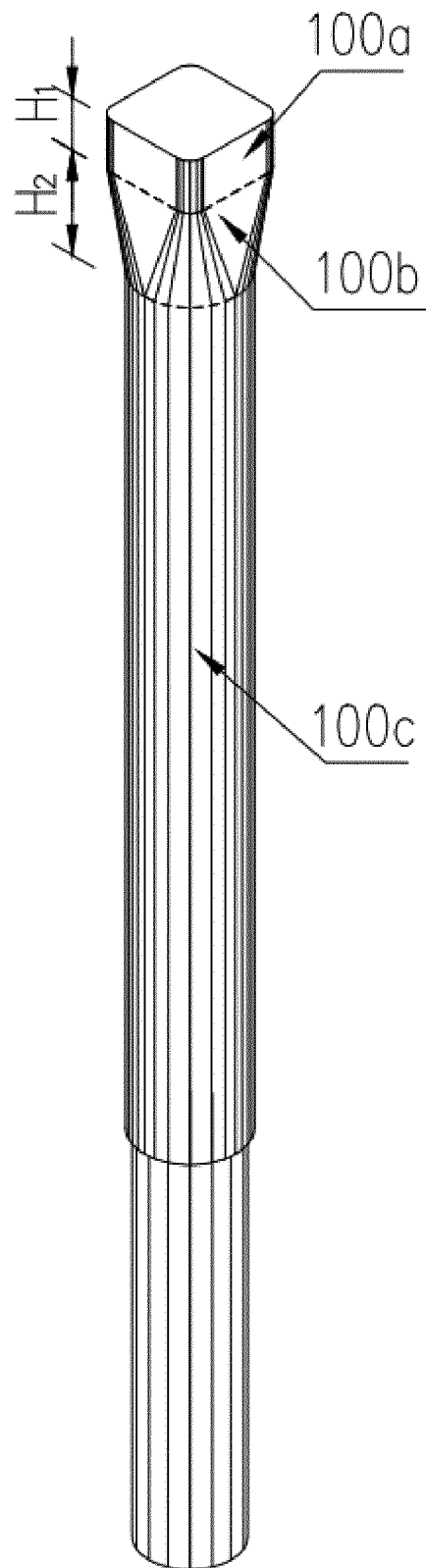


Fig. 5

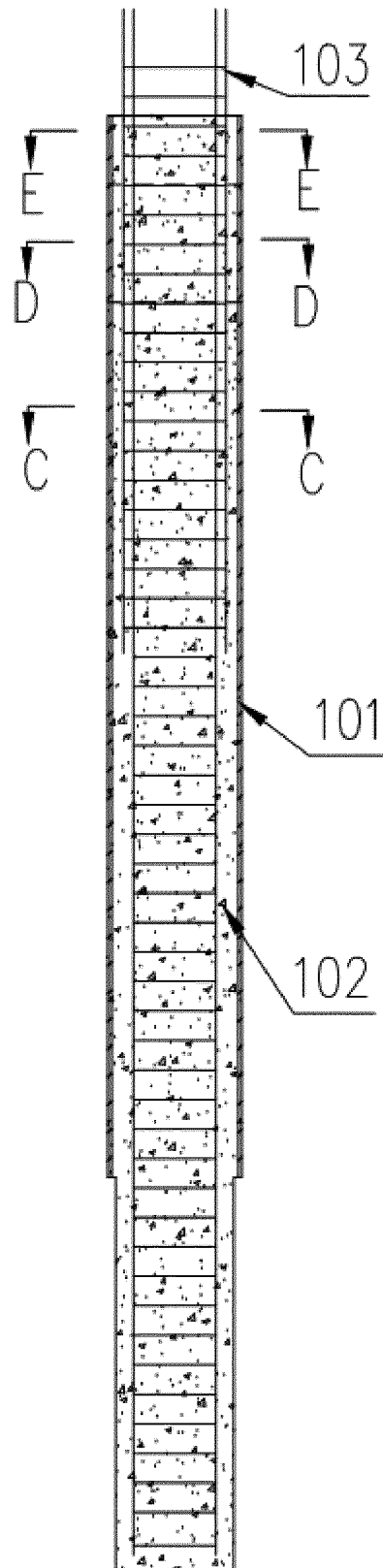


Fig. 6

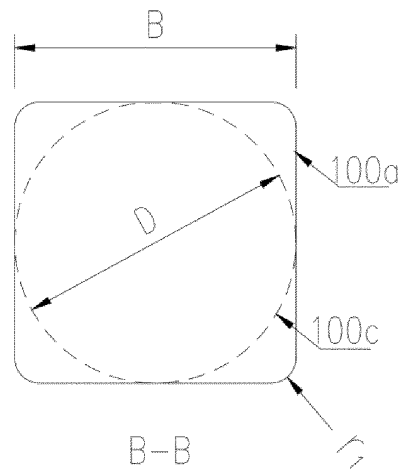


Fig. 7

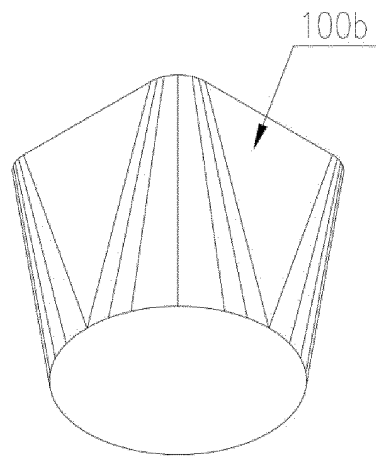


Fig. 8

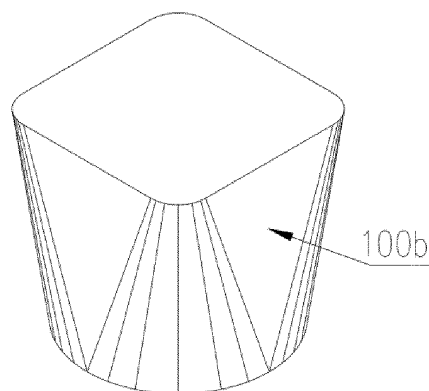


Fig. 9

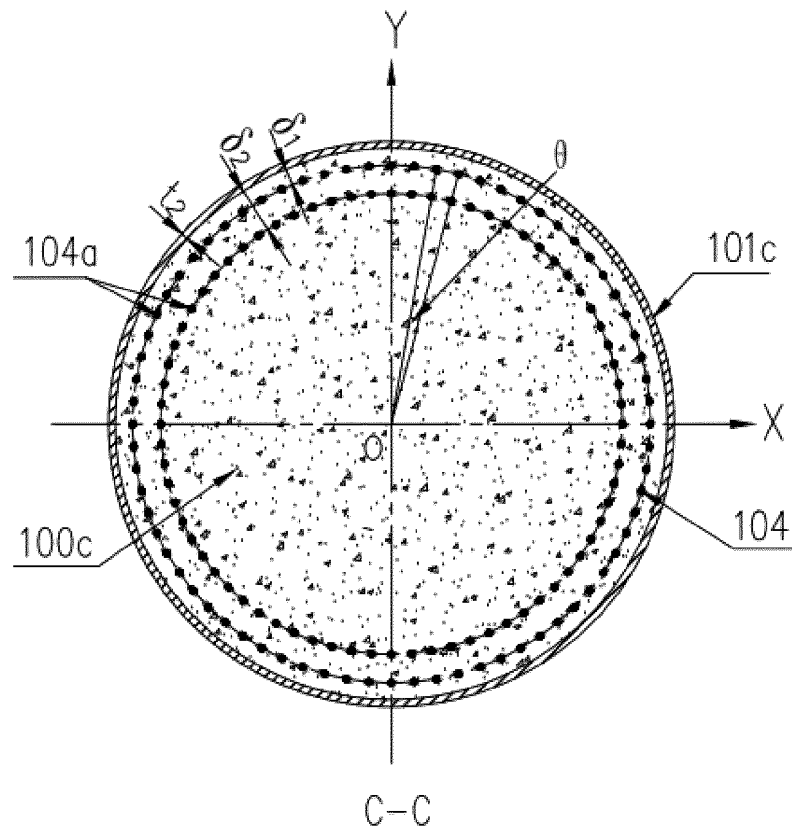


Fig. 10

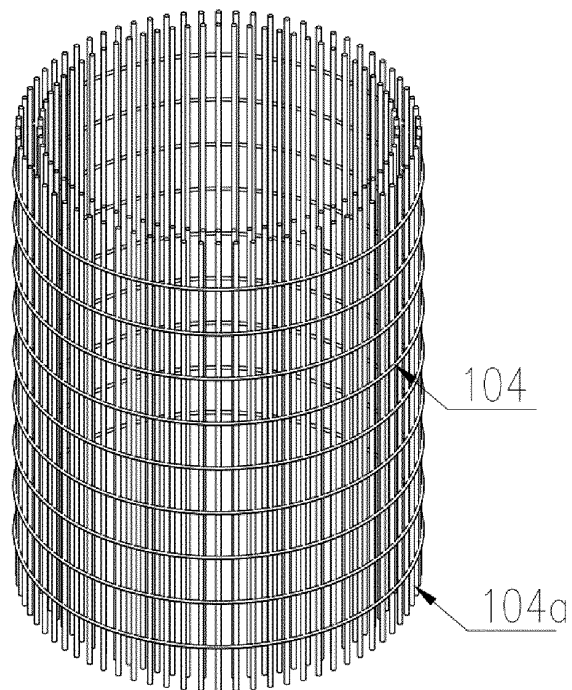


Fig. 11

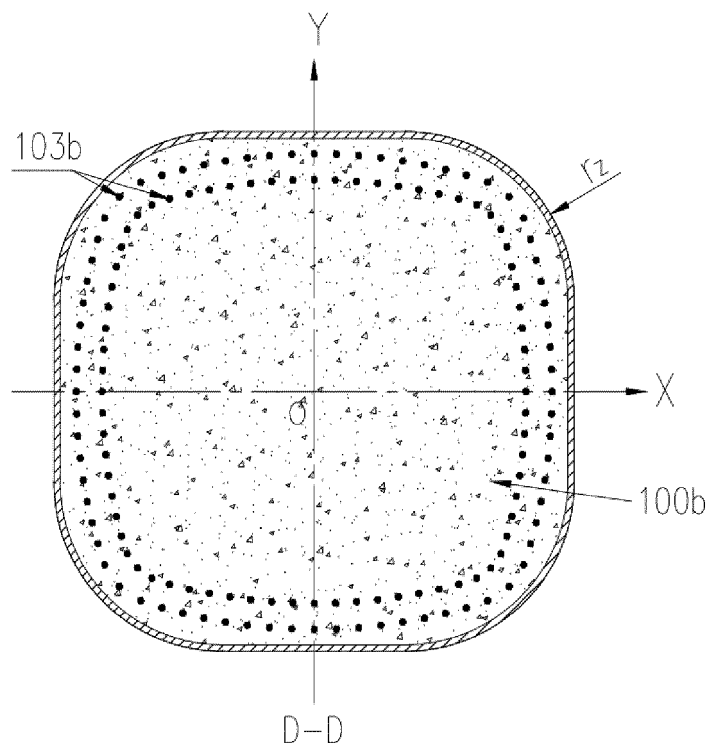


Fig. 12

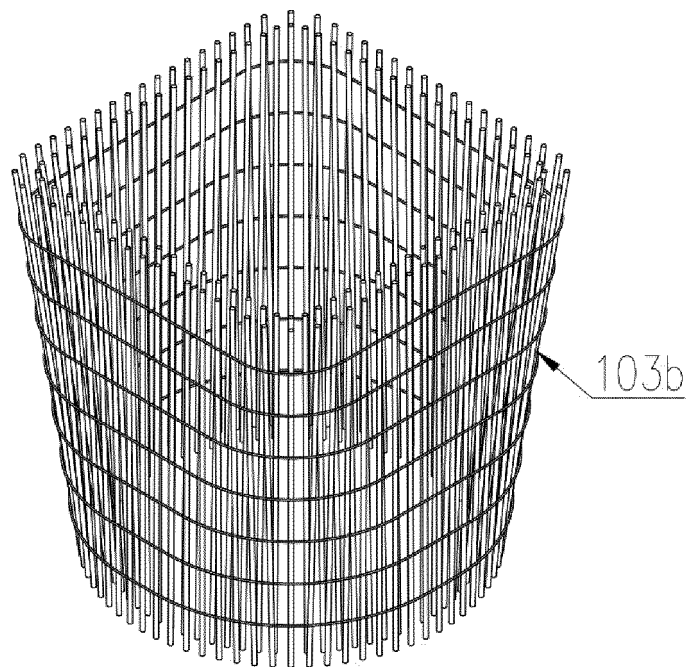


Fig. 13

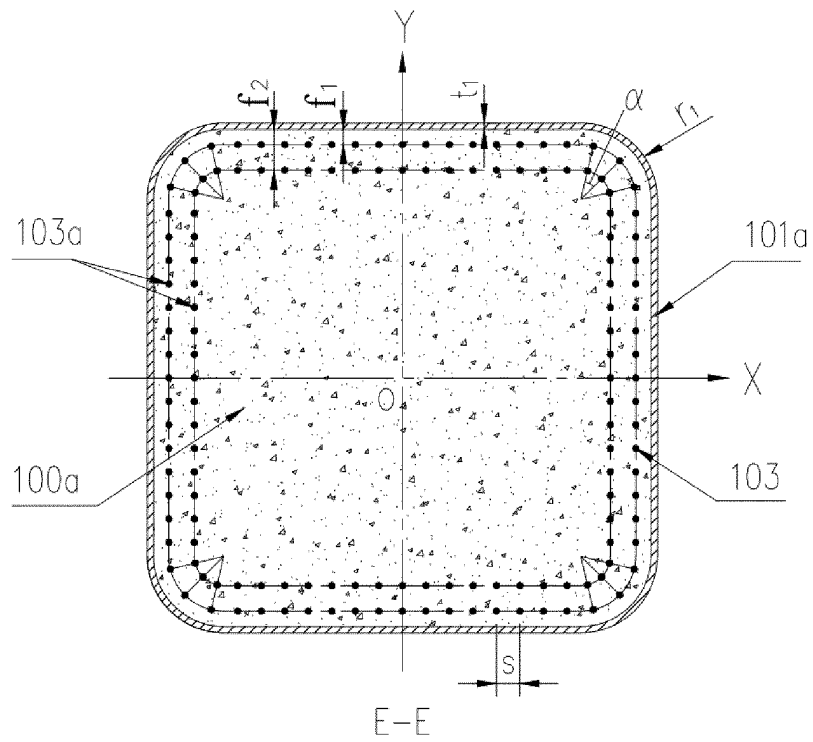


Fig. 14

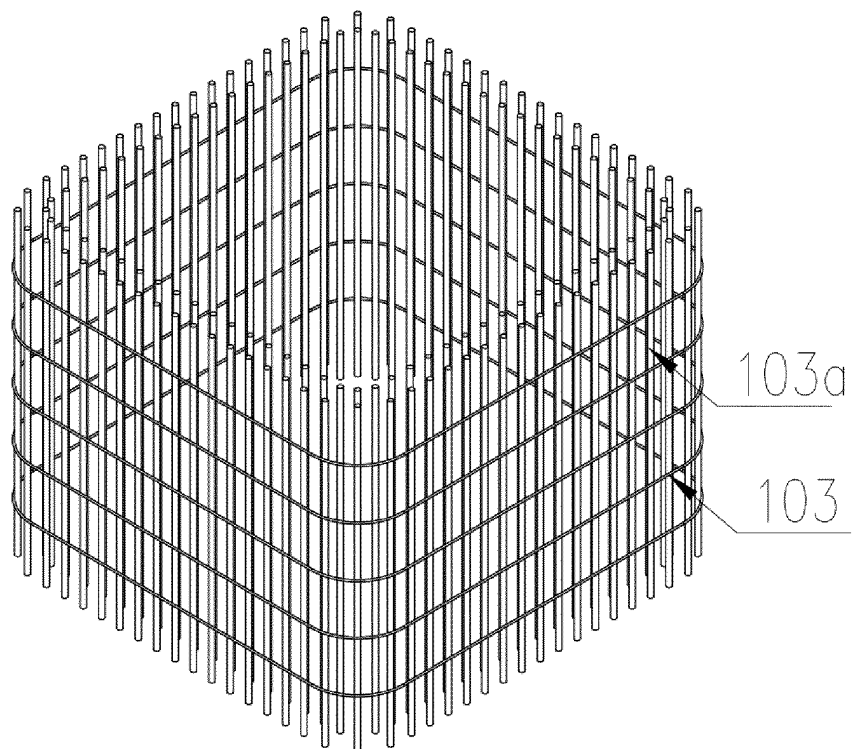


Fig. 15

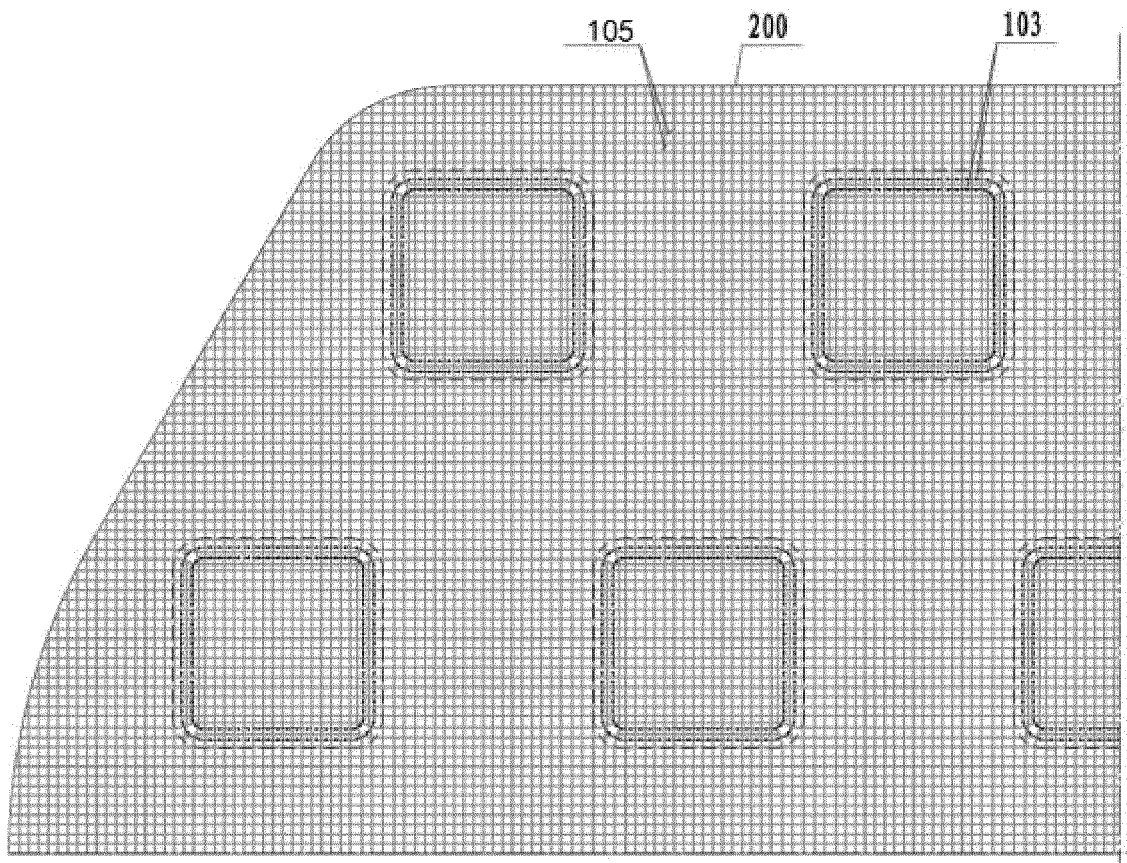


Fig. 16

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/115223

A. CLASSIFICATION OF SUBJECT MATTERE02D 27/52(2006.01)i; E02D 27/14(2006.01)i; E02D 5/34(2006.01)i; E02D 31/12(2006.01)i; E02D 19/04(2006.01)i;
E01D 19/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E02D27/-;E02D5/-;E02D31/-;E02D19/-;E01D19/-

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT, CNABS, WPABSC, ENTXTC, DWPI, SIPOABS, ENTXT, OETXT, 中国期刊网全文数据库, CJFD: 中铁大桥勘测设计院集团有限公司, 肖海珠, 桩, 群桩, 钻孔桩, 承台, 平台, 基础, 封板, 垫层, 深水, 海, 圆, 方形, 钢筋笼, 钢筋, 混凝土; pile?, drill+ 2d pile?, cap?, bear+, platform?, foundation, seal+, plate?, concrete, beton, sea, deepwater, arc+, square, cage?, steel 2d bar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 111411638 A (SHIJIAZHANG TIEDAO UNIVERSITY) 14 July 2020 (2020-07-14) description, specific embodiments, and figures 1-6	1-10
Y	CN 208685645 U (CCCC FIRST HIGHWAY XIAMEN ENGINEERING CO., LTD. et al.) 02 April 2019 (2019-04-02) description, specific embodiments, and figures 1-4	1-10
Y	WO 2014037824 A1 (UAB HIDROSFERA) 13 March 2014 (2014-03-13) description, specific embodiments, and figures 1-3	1-10
Y	CN 101709580 A (GUANGDONG SANHE PIPE CO., LTD.) 19 May 2010 (2010-05-19) description, specific embodiments, and figures 1-3	1-10
Y	CN 207714309 U (SHANGHAI ARCHITECTURAL AND ENGINEERING CONSULTANTS CO., LTD.) 10 August 2018 (2018-08-10) description, specific embodiments, and figures 1-2	1-10
Y	CN 209243708 U (ZHENJIANG PLANNING AND DESIGN RESEARCH INSTITUTE) 13 August 2019 (2019-08-13) description, specific embodiments, and figures 1-3	1-10

☒ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/115223

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